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**UTILITY  
PATENT APPLICATION  
TRANSMITTAL**

Attorney Docket No.

K35A0680

Total Pages

First Named Inventor or Application Identifier

ROBERT P. RYAN

Express Mail Label No.

EI266880098US

(Only for new nonprovisional applications under 37 CFR 1.53(b))

**APPLICATION ELEMENTS**

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO:

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1. ☒ Fee Transmittal Form  
(Submit an original, and a duplicate for fee processing)
2. ☒ Specification [Total Pages **11**]  
(preferred arrangement set forth below)
- Descriptive title of the Invention
  - Cross References to Related Applications
  - Statement Regarding Fed sponsored R & D
  - Reference to Microfiche Appendix
  - Background of the Invention
  - Brief Summary of the Invention
  - Brief Description of the Drawings (if filed)
  - Detailed Description
  - Claim(s)
  - Abstract of the Disclosure
3. ☒ Drawing(s) (35 USC 113) [Total Sheets **4**]  
☒ Formal ☐ Informal
4. Oath or Declaration [Total Pages **1**]
- a. ☒ Newly executed (original or copy)
- b. ☐ Copy from a prior application (37 CFR 1.63(d))  
(for continuation/divisional with Box 17 completed)  
[Note Box 5 below]
- i. ☐ DELETION OF INVENTOR(S)  
Signed statement attached deleting  
inventor(s) named in the prior application,  
see 37 CFR 1.63(d)(2) and 1.33(b).
5. ☐ Incorporation By Reference (useable if Box 4b is checked)  
The entire disclosure of the prior application, from which a  
copy of the oath or declaration is supplied under Box 4b,  
is considered as being part of the disclosure of the  
accompanying application and is hereby incorporated by  
reference therein.

6. ☐ Microfiche Computer Program (Appendix)
7. Nucleotide and/or Amino Acid Sequence Submission  
(if applicable, all necessary)
- a. ☐ Computer Readable Copy
- b. ☐ Paper Copy (identical to computer copy)
- c. ☐ Statement verifying identity of above copies

**ACCOMPANYING APPLICATION PARTS**

8. ☒ Assignment Papers (cover sheet & document(s))
9. ☐ 37 CFR 3.73(b) Statement (when there is an assignee) ☒ Power of Attorney
10. ☐ English Translation Document (if applicable)
11. ☐ Information Disclosure Statement (IDS)/PTO-1449 ☐ Copies of IDS Citations
12. ☐ Preliminary Amendment
13. ☒ Return Receipt Postcard (MPEP 503)  
(Should be specifically itemized)
14. ☐ Small Entity ☐ Statement filed in prior application,  
Statement(s) ☐ Status still proper and desired
15. ☐ Certified Copy of Priority Document(s)  
(if foreign priority is claimed)
16. ☒ Other: Bibliographic Data

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<b>FEE TRANSMITTAL</b>  <i>Note: Effective October 1, 1997. Patent fees are subject to annual revision.</i>	<b>Complete if Known</b>												
	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%;">Application Number</td> <td>UNKNOWN</td> </tr> <tr> <td>Filing Date</td> <td>HEREWITH</td> </tr> <tr> <td>First Named Inventor</td> <td>ROBERT P. RYAN</td> </tr> <tr> <td>Group Art Unit</td> <td>UNKNOWN</td> </tr> <tr> <td>Examiner Name</td> <td>UNKNOWN</td> </tr> <tr> <td>Attorney Docket Number</td> <td>K35A0680</td> </tr> </table>	Application Number	UNKNOWN	Filing Date	HEREWITH	First Named Inventor	ROBERT P. RYAN	Group Art Unit	UNKNOWN	Examiner Name	UNKNOWN	Attorney Docket Number	K35A0680
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<b>TOTAL AMOUNT OF PAYMENT</b> (\$) <b>750.00</b>													

<b>METHOD OF PAYMENT (check one)</b>  1. <input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge indicated fees and credit any over payments to: Deposit Account Number: <b>23-1209</b> Deposit Account Name: <b>WESTERN DIGITAL CORPORATION</b> <input checked="" type="checkbox"/> Charge Any Additional Fee Required Under 37 CFR 1.16 and 1.17 <input type="checkbox"/> Charge the Issue Fee Set in 37 CFR 1.18 at the Mailing of the Notice of Allowance  2. <input type="checkbox"/> Payment Enclosed: <input type="checkbox"/> Check <input type="checkbox"/> Money Order <input type="checkbox"/> Other	<b>FEE CALCULATION (continued)</b>  <b>3. ADDITIONAL FEES</b> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>Large Entity Fee Code</th> <th>Small Entity Fee Code</th> <th>Fee Description</th> <th>Fee Paid</th> </tr> </thead> <tbody> <tr><td>105 130 205 65</td><td></td><td>Surcharge - late filing fee or oath</td><td></td></tr> <tr><td>127 50 227 25</td><td></td><td>Surcharge - late provisional filing fee or cover sheet.</td><td></td></tr> <tr><td>139 130 139 130</td><td></td><td>Non-English specification</td><td></td></tr> <tr><td>147 2,520 147 2,520</td><td></td><td>For filing a request for reexamination</td><td></td></tr> <tr><td>112 920* 112 920*</td><td></td><td>Requesting publication of SIR prior to Examiner action</td><td></td></tr> <tr><td>113 1,840* 113 1,840*</td><td></td><td>Requesting publication of SIR after Examiner action</td><td></td></tr> <tr><td>115 110 215 55</td><td></td><td>Extension for reply within first month</td><td></td></tr> <tr><td>116 390 216 195</td><td></td><td>Extension for reply within second month</td><td></td></tr> <tr><td>117 890 217 445</td><td></td><td>Extension for reply within third month</td><td></td></tr> <tr><td>118 1,390 218 695</td><td></td><td>Extension for reply within fourth month</td><td></td></tr> <tr><td>128 1,890 228 945</td><td></td><td>Extension for reply within fifth month</td><td></td></tr> <tr><td>119 310 219 155</td><td></td><td>Notice of Appeal</td><td></td></tr> <tr><td>120 310 220 155</td><td></td><td>Filing a brief in support of an appeal</td><td></td></tr> <tr><td>121 270 221 135</td><td></td><td>Request for oral hearing</td><td></td></tr> <tr><td>138 1,510 138 1,510</td><td></td><td>Petition to institute a public use proceeding</td><td></td></tr> <tr><td>140 110 240 55</td><td></td><td>Petition to revive - unavoidable</td><td></td></tr> <tr><td>141 1,240 241 620</td><td></td><td>Petition to revive - unintentional</td><td></td></tr> <tr><td>142 1,240 242 620</td><td></td><td>Utility issue fee (or reissue)</td><td></td></tr> <tr><td>143 440 243 220</td><td></td><td>Design issue fee</td><td></td></tr> <tr><td>144 600 244 300</td><td></td><td>Plant issue fee</td><td></td></tr> <tr><td>122 130 122 130</td><td></td><td>Petitions to the Commissioner</td><td></td></tr> <tr><td>123 50 123 50</td><td></td><td>Petitions related to provisional applications</td><td></td></tr> <tr><td>126 240 126 240</td><td></td><td>Submission of Information Disclosure Stmt</td><td></td></tr> <tr><td>581 40 581 40</td><td></td><td>Recording each patent assignment per property (times number of properties)</td><td>40.00</td></tr> <tr><td>146 710 246 355</td><td></td><td>Filing a submission after final rejection (37 CFR 1.129(a))</td><td></td></tr> <tr><td>149 710 249 355</td><td></td><td>For each additional invention to be examined (37 CFR 1.129(b))</td><td></td></tr> <tr><td colspan="3">Other fee (specify) _____</td><td></td></tr> <tr><td colspan="3">Other fee (specify) _____</td><td></td></tr> <tr> <td colspan="3"> <b>Subtotal (3) (\$)</b> <b>40.00</b> </td> <td></td> </tr> </tbody> </table>	Large Entity Fee Code	Small Entity Fee Code	Fee Description	Fee Paid	105 130 205 65		Surcharge - late filing fee or oath		127 50 227 25		Surcharge - late provisional filing fee or cover sheet.		139 130 139 130		Non-English specification		147 2,520 147 2,520		For filing a request for reexamination		112 920* 112 920*		Requesting publication of SIR prior to Examiner action		113 1,840* 113 1,840*		Requesting publication of SIR after Examiner action		115 110 215 55		Extension for reply within first month		116 390 216 195		Extension for reply within second month		117 890 217 445		Extension for reply within third month		118 1,390 218 695		Extension for reply within fourth month		128 1,890 228 945		Extension for reply within fifth month		119 310 219 155		Notice of Appeal		120 310 220 155		Filing a brief in support of an appeal		121 270 221 135		Request for oral hearing		138 1,510 138 1,510		Petition to institute a public use proceeding		140 110 240 55		Petition to revive - unavoidable		141 1,240 241 620		Petition to revive - unintentional		142 1,240 242 620		Utility issue fee (or reissue)		143 440 243 220		Design issue fee		144 600 244 300		Plant issue fee		122 130 122 130		Petitions to the Commissioner		123 50 123 50		Petitions related to provisional applications		126 240 126 240		Submission of Information Disclosure Stmt		581 40 581 40		Recording each patent assignment per property (times number of properties)	40.00	146 710 246 355		Filing a submission after final rejection (37 CFR 1.129(a))		149 710 249 355		For each additional invention to be examined (37 CFR 1.129(b))		Other fee (specify) _____				Other fee (specify) _____				<b>Subtotal (3) (\$)</b> <b>40.00</b>			
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Typed or Printed Name	Milad G. Shara, Esq.	Reg. Number	39,367
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## Application Information

Title Line One :: DISK DRIVE COMPRISING VCM STALL DETECTOR FOR VELOCITY  
Title Line Two:: CONTROL OF AN ACTUATOR ARM  
Formal Drawings :: Yes  
Application Type :: Utility  
Docket Number :: K35A0680  
Licensed - U S Government Agency :: N/A  
Contract Number :: N/A  
Grant Number :: N/A  
Secrecy Order in Parent Application :: N/A

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Registration Number Two:: 37,938

**DISK DRIVE COMPRISING VCM STALL DETECTOR FOR VELOCITY CONTROL  
OF AN ACTUATOR ARM**

**CROSS REFERENCE TO RELATED APPLICATIONS AND PATENTS**

This application is related to co-pending patent application serial no. 09/\_\_\_\_,\_\_\_\_ entitled "DISK DRIVE EMPLOYING VCM DEMAND CURRENT TO CALIBRATE VCM IR VOLTAGE FOR VELOCITY CONTROL OF AN ACTUATOR ARM", and serial no. 09/\_\_\_\_,\_\_\_\_ entitled "DISK DRIVE EMPLOYING SEEK TIME VCM IR VOLTAGE CALIBRATION FOR VELOCITY CONTROL OF AN ACTUATOR ARM", both filed concurrently with the present application, the disclosures of which are incorporated herein by reference.

**BACKGROUND OF THE INVENTION**

**Field of the Invention**

The present invention relates to disk drives for computer systems. More particularly, the present invention relates to a disk drive comprising a VCM stall detector for velocity control of an actuator arm.

**Description of the Prior Art**

Disk drives comprise a disk and a head connected to a distal end of an actuator arm which is rotated about a pivot by a voice coil motor (VCM) to position the head radially over the disk. The disk comprises a plurality of radially spaced, concentric tracks for recording user data sectors and embedded servo sectors. The embedded servo sectors comprise head positioning information (e.g., a track address) which is read by the head and processed by a servo control system to control the velocity of the actuator arm as it seeks from track to track.

There are times when the servo control system does not have access to the embedded servo sectors yet it is still desirable to control the velocity of the actuator arm. For example, in disk drives wherein the head is parked on a landing-zone of the disk, it is desirable to control the

1 velocity of the actuator arm to unlatch the head during spin-up. In disk drives employing ramp  
2 loading/unloading, it is desirable to control the velocity of the actuator arm so that the head is not  
3 damaged as it travels off the ramp onto the disk as well as off the disk onto the ramp. Another  
4 example is if the servo control system loses servo sector synchronization it is desirable to control  
5 the velocity of the actuator arm to facilitate re-synchronizing to the servo sectors.

6 Prior art techniques for controlling the velocity of the actuator arm when servo sector  
7 information is unavailable include using a voltage loop with the detected back EMF generated by  
8 the VCM as the feedback. The VCM is essentially an RLC circuit where R is resistance, L  
9 inductance, and C the inertia of the motor and load. The voltage contribution of C to the  
10 measured back EMF is proportional to the velocity of the VCM. Since the resistance R is in  
11 series with C, it is desirable to cancel R's contribution to the back EMF leaving only LC. Once  
12 the resistance R is canceled, at low frequencies  $L di/dt$  is small leaving the voltage contribution of  
13 C as the dominant factor in the measured back EMF.

14 Prior art techniques for performing VCM resistance compensation include calibrating and  
15 subtracting from the measured back EMF the voltage contribution of R (i.e., the IR voltage  
16 where I is the current in the VCM). The VCM resistance R is measured by applying a fixed  
17 current to the VCM in order to press the actuator arm against a fixed object (e.g., the crash-stop  
18 for stopping the head at the inner diameter (ID)). With the actuator arm pressed against the fixed  
19 object, the velocity is zero and  $L di/dt$  is zero, leaving the VCM resistance R as the only  
20 contribution to the measured back EMF.

21 If the IR voltage is completely canceled from the measured back EMF, it would result in  
22 an under-damped or unstable system. Thus, it is desirable to decrease the measured VCM  
23 resistance R by a small offset to leave a relatively small amount of IR voltage in the measured  
24 back EMF. It is also desirable to detect when the motor stalls to prevent overheating and  
25 oversteering the VCM. The VCM will stall, for example, at the end of an unload (or parking)  
26 operation when the head latches, at the beginning of a load (or unparking) operation if the head  
27 fails to unlatch, or if the drive fails to synchronize to the embedded servo sectors during a load

1 operation and the actuator arm crashes into the ID crash-stop. Detecting a failure to unlatch  
2 during a load (unpark) operation also saves time during drive initialization. However, because a  
3 small amount of VCM resistance  $R$  is not canceled to achieve an over-damped system, when the  
4 VCM stalls the measured back EMF will actually rise giving a false indication that the actuator  
5 arm is still moving.

6 There is, therefore, a need to detect VCM stall conditions to prevent overheating and  
7 overstressing the VCM, while still allowing a small amount of effective VCM resistance  $R$  to  
8 achieve an over-damped velocity controlled system.

## 10 SUMMARY OF THE INVENTION

11 The present invention may be regarded as a disk drive comprising a disk, a head, an  
12 actuator arm for actuating the head radially over the disk, and a voice coil motor (VCM) for  
13 rotating the actuator arm about a pivot, the VCM comprising a coil comprising a VCM resistance  
14  $R$ . A back EMF voltage detector measures a back EMF voltage across the coil, and a current  
15 detector detects a current  $I$  flowing through the coil. An IR voltage detector, responsive to the  
16 current  $I$  detected by the current detector, detects an IR voltage proportional to the current  $I$  times  
17 the VCM resistance  $R$ . A voltage compensator substantially cancels the IR voltage from the  
18 measured back EMF voltage to generate a compensated back EMF voltage. A control voltage  
19 generator, responsive to the compensated back EMF voltage, generates a control voltage applied to  
20 the coil to generate the current  $I$  flowing through the coil. A stall detector compares the current  $I$   
21 detected by the current detector to a threshold, wherein a VCM stall condition is detected if the  
22 current  $I$  exceeds the threshold for a predetermined interval.

23 In one embodiment, the current detector comprises a sense resistor in series with the coil.  
24 In another embodiment, the stall detector comprises a clock and a counter for counting a number  
25 of clock cycles the current  $I$  exceeds the threshold.

26 The present invention may also be regarded as a method of controlling velocity of an  
27 actuator arm in a disk drive. The disk drive comprises a disk, a head, the actuator arm, and a

voice coil motor (VCM) for rotating the actuator arm about a pivot. The VCM comprises a coil comprising a VCM resistance  $R$ . A control voltage is generated from a command input and a compensated back EMF voltage. The control voltage is applied to the coil to generate a current  $I$  flowing through the coil to move the actuator arm during a seek operation. A back EMF voltage across the coil, a current  $I$  flowing through the coil, and an  $IR$  voltage proportional to the current  $I$  times the VCM resistance  $R$ , are detected. The  $IR$  voltage is subtracted from the back EMF voltage detected across the coil to generate the compensated back EMF voltage. The current  $I$  is compared to a threshold, and a VCM stall condition is detected if the current  $I$  exceeds the threshold for a predetermined interval.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a disk drive according to an embodiment of the present invention as comprising a back EMF voltage detector, a current detector, an  $IR$  voltage detector, a voltage compensator for substantially canceling the  $IR$  voltage from the back EMF voltage measurement, and a stall detector for detecting a VCM stall condition.

FIG. 2 shows suitable circuitry for implementing the components in the disk drive shown in FIG. 1.

FIG. 3 shows suitable circuitry for implementing the high-current time-out detector of FIG. 3.

FIG. 4A is a timing diagram illustrating various signals in the disk drive during a velocity mode unload operation.

FIG. 4B is a timing diagram illustrating various signals in the disk drive during a power-on reset or speed-fault unload condition.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 shows a disk drive 2 according to an embodiment of the present invention as comprising a disk 4, a head 6, an actuator arm 8 for actuating the head 6 radially over the disk 4,

1 and a voice coil motor (VCM) 12 for rotating the actuator arm 8 about a pivot, the VCM 12  
2 comprising a coil 14 comprising a VCM resistance R. A back EMF voltage detector 16  
3 measures a back EMF voltage 16 across the coil 14, and a current detector 20 detects a current I  
4 22 flowing through the coil 14. An IR voltage detector 24, responsive to the current I 22  
5 detected by the current detector 20, detects an IR voltage 26 proportional to the current I 22 times  
6 the VCM resistance R. A voltage compensator 28 substantially cancels the IR voltage 26 from  
7 the measured back EMF voltage 18 to generate a compensated back EMF voltage 30. A control  
8 voltage generator 32, responsive the compensated back EMF voltage 30, generates a control  
9 voltage 34 applied to the coil 14 to generate the current I 22 flowing through the coil 14. A stall  
10 detector 36 compares the current I 22 detected by the current detector 20 to a threshold, wherein  
11 a VCM stall condition 38 is detected if the current I 22 exceeds the threshold for a predetermined  
12 interval.

13 In the embodiment of FIG. 1, a command input 40 is generated by a servo control system  
14 (not shown) which controls the desired radial position of the head 6 with respect to the tracks  
15 recorded on the disk 4. The command input 40 may also be set independent of the servo  
16 controller, for example, to facilitate parking the head 6 during a power failure or spindle speed  
17 fault mode.

18 FIG. 2 shows suitable circuitry for implementing the control voltage generator 32, back  
19 EMF voltage detector 16, current detector 20, IR voltage detector 24, and voltage compensator  
20 28 of FIG. 1. Other circuitry, firmware, or combinations thereof may be employed in alternative  
21 embodiments. The circuit of FIG. 2 operates in a normal operating mode wherein the VCM 12 is  
22 driven by a current controlled feedback loop, and in a velocity control mode wherein the VCM  
23 12 is driven by a voltage controlled feedback loop. When in the normal operating mode, switch  
24 44A is opened and switch 44B is closed to configure the current feedback loop, and when in  
25 the velocity control mode, switch 44A is closed and switch 44B is opened to configure the  
26 voltage feedback loop. A velocity mode control signal 46 configures the switches 44A and 44B  
27 for velocity control mode when the embedded servo information is not available for servo



controlling the velocity of the actuator arm 8. A velocity bit 48 may be set by a controller (e.g., a servo controller) to activate the velocity mode control signal 46 via OR gate 50. The velocity bit 48 may be set during controlled modes of operation, such as during a load/unload operation or when synchronization to the embedded servo data is lost. The velocity mode control signal 46 may also be activated via AND gate 52 and OR gate 50 during power down or power failure. If the OE UNLOAD signal 58 has been preset to configure the drive for velocity mode unload, when a power down or power failure is detected, the control signals OUTPUT ENABLE (OE) 54 and TPARK1 56 are automatically activated, thereby activating the velocity mode control signal 46.

A digital-to-analog (D/A) converter 60 generates an analog VCM command signal 62 in response to a digital command input signal 63. A digital register 64 is programmed with an operating command input during normal operation, and a digital register 66 is programmed with a velocity mode command input used during power down or power failure to park the head 6. A digital register 68 stores a calibrated VCM resistance R value 72 for use during velocity control mode when the velocity bit 48 is activated (e.g., when calibrating the detected IR voltage 26). After calibrating the detected IR voltage 26 a digital register 70 stores the calibrated VCM resistance R value 72 for use during power down or power failure. The calibrated VCM resistance R value 72 is used to program a programmable resistor 74 in order to calibrate the detected IR voltage 26. For more information on calibrating the IR voltage 26, see the above-referenced co-pending patent applications "DISK DRIVE EMPLOYING VCM DEMAND CURRENT TO CALIBRATE VCM IR VOLTAGE FOR VELOCITY CONTROL OF AN ACTUATOR ARM" and "DISK DRIVE EMPLOYING SEEK TIME VCM IR VOLTAGE CALIBRATION FOR VELOCITY CONTROL OF AN ACTUATOR ARM."

A sense resistor 78 and amplifier 80 implement a suitable current detector 20 for a voltage representing the current I 22 flowing through the coil 14. With the voltage representing the current I 22 applied to the programmable resistor 74, the output of amplifier 76 is the calibrated IR voltage 26. An amplifier 82 measures the back EMF voltage 18 across the coil 14.

The IR voltage 26 is subtracted from the measured back EMF voltage 18 such that the output voltage of amplifier 84 is the compensated back EMF voltage 30. The compensated back EMF voltage 30 is amplified by amplifier 84, and filtered by amplifier 86 and capacitor 88 to generate a velocity feed back voltage 90 representative of the velocity of the actuator arm 8. The velocity feedback voltage 90 is subtracted from the VCM command signal 62 to generate the control voltage 34 applied to the coil 14.

The stall detector 36 monitors the current I 22 flowing through the coil 14 to detect when the VCM 12 has stalled. Details of suitable circuitry for implementing the stall detector 36 are shown in FIG. 3. The current I 22 detected by the current detector 20 is compared to a positive threshold by comparator 92A and to a negative threshold by comparator 92B. If the current I exceeds either the positive or negative thresholds, a high-current signal 94 is activated via OR gate 96. The high-current signal 94 enables a counter 98 which begins counting cycles of a clock 100. If the high-current signal 94 is active for a predetermined interval (number of clock cycles), then a VCM stall condition 38 is detected. The velocity mode signal 46 enables the stall detector 36 via AND gate 102 so that the VCM stall condition 38 can only be detected during the velocity control mode.

FIG. 4A is a timing diagram illustrating operation of the stall detector 36 during a normal (non-power failure) ramp unload operation wherein the head 6 is parked on a ramp at the periphery of the disk 4. At time T0 the disk drive is in a sleep mode prior to the ramp unload operation. At time T1, the current I 22 is increased to begin moving the head 6 toward the ramp, and when the head 6 reaches the ramp, the current I 22 is increased again to move the head 6 off the disk 4 onto the beginning of the ramp. The current I 22 is then held substantially constant to move the head 6 up the ramp at a substantially constant velocity. During this interval, the current I 22 does not exceed the threshold of the stall detector 36. When the head 6 reaches the end of the ramp, the current I 22 begins to ramp and at time T2 and exceeds the threshold of the stall detector 36 activating the high-current signal 94. At time T3 a stall condition 38 is detected due to the high-current signal 94 being active for the predetermined interval of the stall detector 36.

1 The current I 22 is turned off in response to the stall condition 38 in order to prevent overheating  
2 and overstressing the VCM 12.

3 FIG. 4B is a timing diagram illustrating operation of the stall detector 36 during an  
4 emergency ramp unload operation (e.g., during a power-on reset (POR), power failure, or speed  
5 fault condition). At time T0, the disk drive begins performing a seek toward the outer diameter  
6 of the disk 4. At time T1, a power failure is detected and the velocity mode 46 is activated. The  
7 current I 22 is ramped with opposite polarity to decelerate the actuator arm 8, and at time T2, the  
8 current I 22 exceeds the threshold of the stall detector 36 activating the high-current signal 94.  
9 As the actuator arm 8 decelerates, the current I 22 falls below the threshold of the stall detector  
10 36 thereby deactivating the high-current signal 94. Since the duration of the high-current signal  
11 94 does not exceed the predetermined interval of the stall detector 36, a stall condition 38 is not  
12 detected as desired. When the head 6 reaches the end of the ramp, the current I 22 begins to  
13 ramp and at time T3 and exceeds the threshold of the stall detector 36 activating the high-current  
14 signal 94. At time T4 a stall condition 38 is detected due to the high-current signal 94 being  
15 active for the predetermined interval of the stall detector 36. The current I 22 is turned off in  
16 response to the stall condition 38 in order to prevent overheating and overstressing the VCM 12.

17 Detecting when the current I 22 exceeds a predetermined threshold to detect a stall  
18 condition, rather than detecting when the compensated back EMF voltage 30 falls to zero, allows  
19 a small amount of VCM resistance R to remain in the calibrated IR voltage 26, thereby achieving  
20 an over-damped, stable velocity controlled system. Further, not detecting a stall condition until  
21 the current I 22 exceeds a predetermined threshold for a predetermined interval avoids detecting  
22 false stall conditions as illustrated in FIG. 4B

**WE CLAIM:**

1. A disk drive comprising:
  - (a) a disk;
  - (b) a head;
  - (c) an actuator arm for actuating the head radially over the disk;
  - (d) a voice coil motor (VCM) for rotating the actuator arm about a pivot, the VCM comprising a coil comprising a VCM resistance R;
  - (e) a back EMF voltage detector for measuring a back EMF voltage across the coil;
  - (f) a current detector for detecting a current I flowing through the coil;
  - (g) an IR voltage detector, responsive to the current I detected by the current detector, for detecting an IR voltage proportional to the current I times the VCM resistance R;
  - (h) a voltage compensator for substantially canceling the IR voltage from the measured back EMF voltage to generate a compensated back EMF voltage;
  - (i) a control voltage generator, responsive the compensated back EMF voltage, for generating a control voltage applied to the coil to generate the current I flowing through the coil; and
  - (j) a stall detector for comparing the current I detected by the current detector to a threshold, wherein a VCM stall condition is detected if the current I exceeds the threshold for a predetermined interval.
2. The disk drive as recited in claim 1, wherein the current detector comprises a sense resistor in series with the coil.
3. The disk drive as recited in claim 1, wherein the stall detector comprises:
  - (a) a clock; and
  - (b) a counter for counting a number of clock cycles the current I exceeds the threshold.

- 1 4. A method of controlling velocity of an actuator arm in a disk drive, the disk drive  
2 comprising a disk, a head, the actuator arm, and a voice coil motor (VCM) for rotating  
3 the actuator arm about a pivot, the VCM comprising a coil comprising a VCM resistance  
4 R, the method comprising the steps of:
- 5 (a) generating a control voltage from a command input and a compensated back EMF  
6 voltage;  
7 (b) applying the control voltage to the coil to generate a current I flowing through the coil  
8 to move the actuator arm;  
9 (c) detecting a back EMF voltage across the coil;  
10 (d) detecting the current I flowing through the coil;  
11 (e) detecting an IR voltage proportional to the current I times the VCM resistance R;  
12 (f) subtracting the IR voltage from the detected back EMF voltage to generate the  
13 compensated back EMF voltage;  
14 (g) comparing the current I to a threshold; and  
15 (h) detecting a VCM stall condition if the current I exceeds the threshold for a  
16 predetermined interval.
- 17 5. The method of controlling velocity of an actuator arm as recited in claim 4, wherein the  
18 step of detecting the current I comprises the step of detecting a current flowing through a  
19 sense resistor in series with the coil.
- 20 6. The method of controlling velocity of an actuator arm as recited in claim 4, wherein the  
21 step of detecting a VCM stall condition comprises the step of counting clock cycles while  
22 the current I exceeds the threshold.

**DISK DRIVE COMPRISING VCM STALL DETECTOR FOR VELOCITY CONTROL  
OF AN ACTUATOR ARM**

**ABSTRACT OF THE DISCLOSURE**

The present invention may be regarded as a disk drive comprising a disk, a head, an actuator arm for actuating the head radially over the disk, and a voice coil motor (VCM) for rotating the actuator arm about a pivot, the VCM comprising a coil comprising a VCM resistance R. A back EMF voltage detector measures a back EMF voltage across the coil, and a current detector detects a current I flowing through the coil. An IR voltage detector, responsive to the current I detected by the current detector, detects an IR voltage proportional to the current I times the VCM resistance R. A voltage compensator substantially cancels the IR voltage from the measured back EMF voltage to generate a compensated back EMF voltage. A control voltage generator, responsive to the compensated back EMF voltage, generates a control voltage applied to the coil to generate the current I flowing through the coil. A stall detector compares the current I detected by the current detector to a threshold, wherein a VCM stall condition is detected if the current I exceeds the threshold for a predetermined interval.

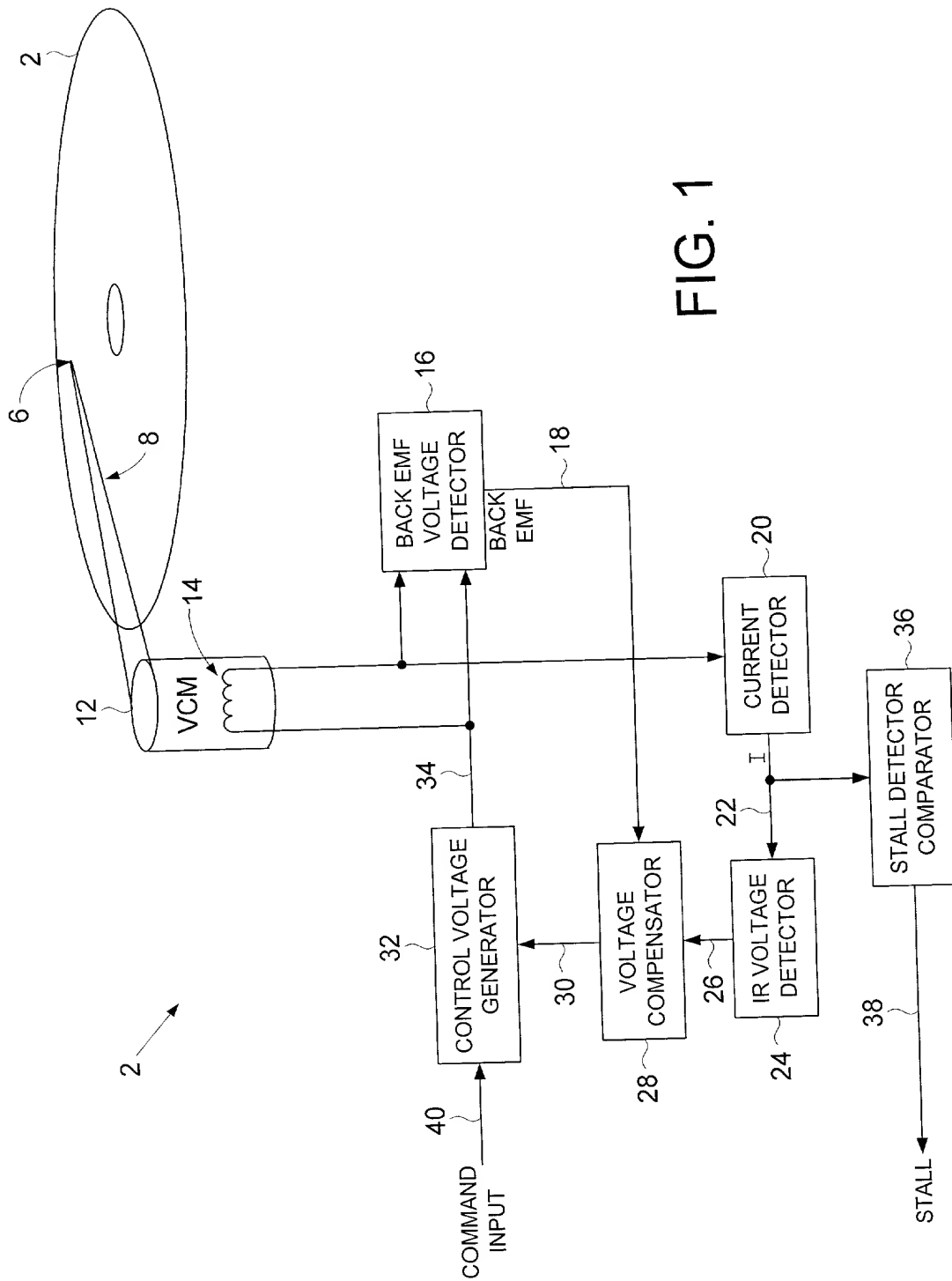
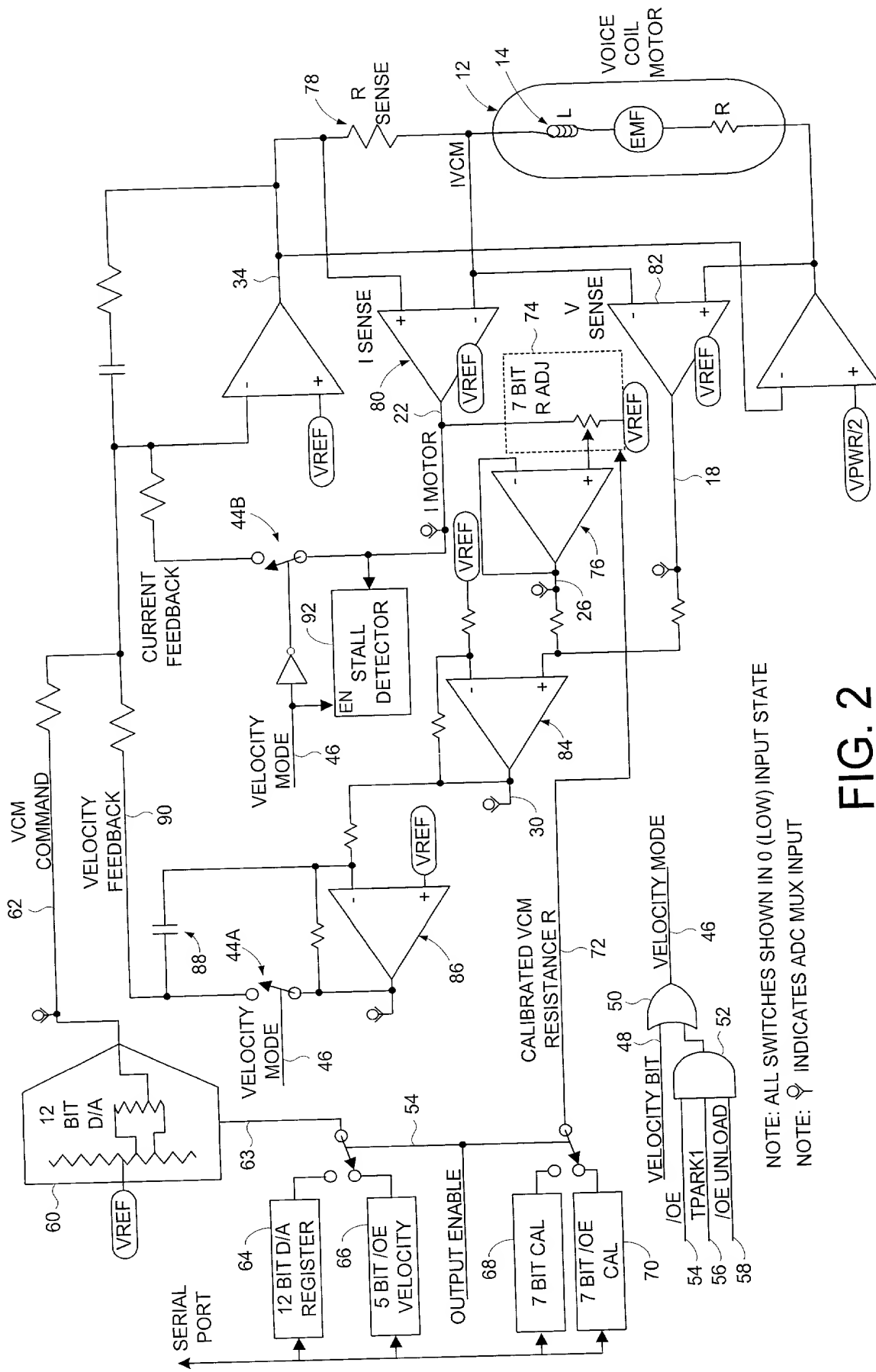


FIG. 1



**FIG. 2**



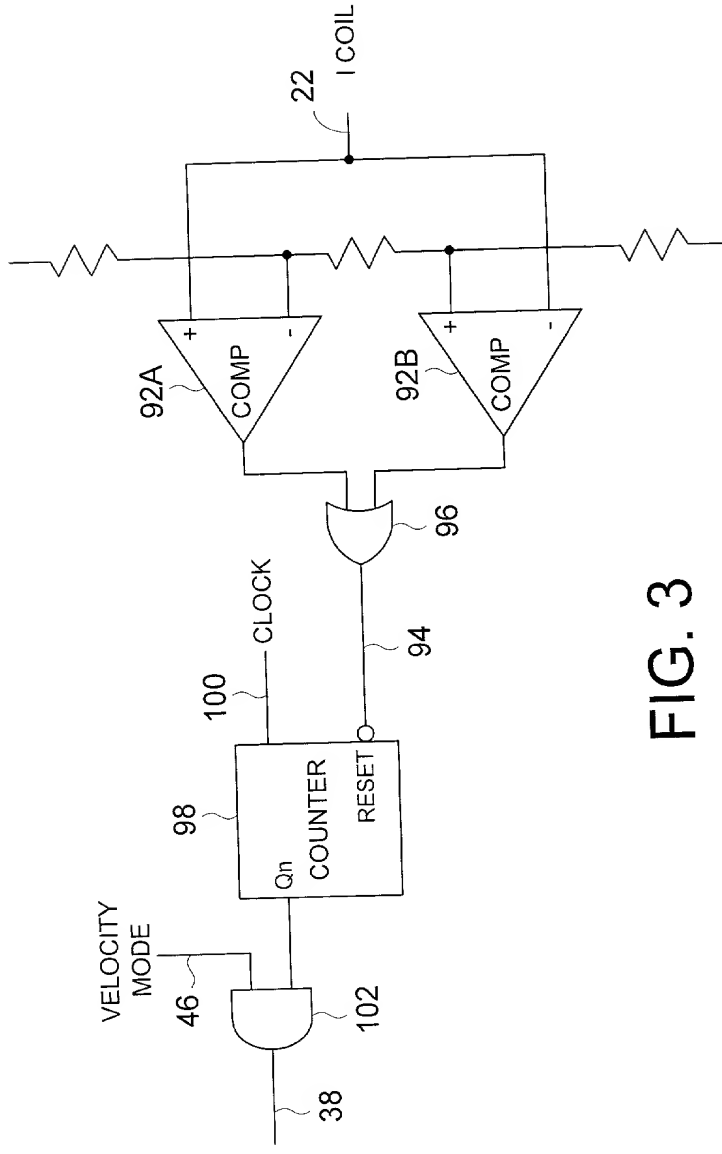
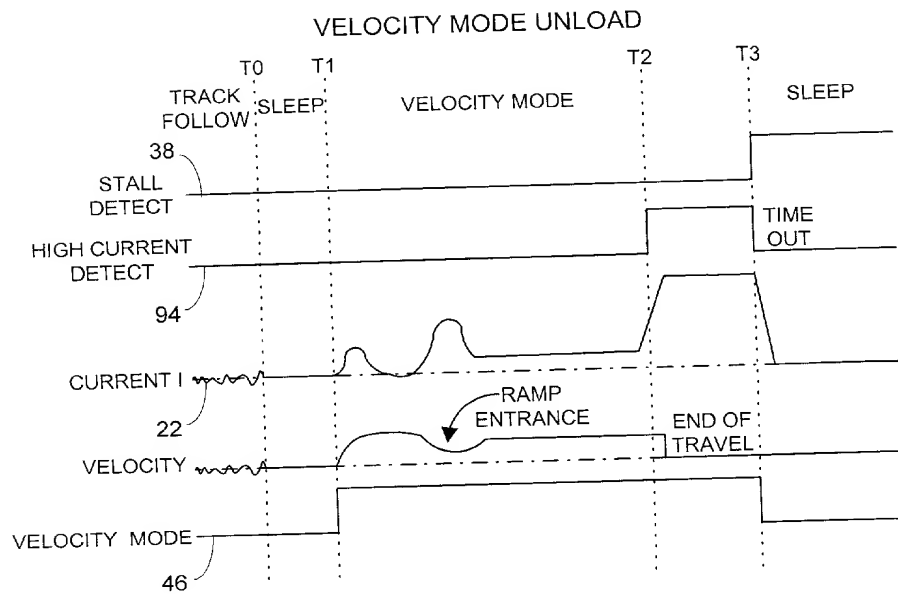
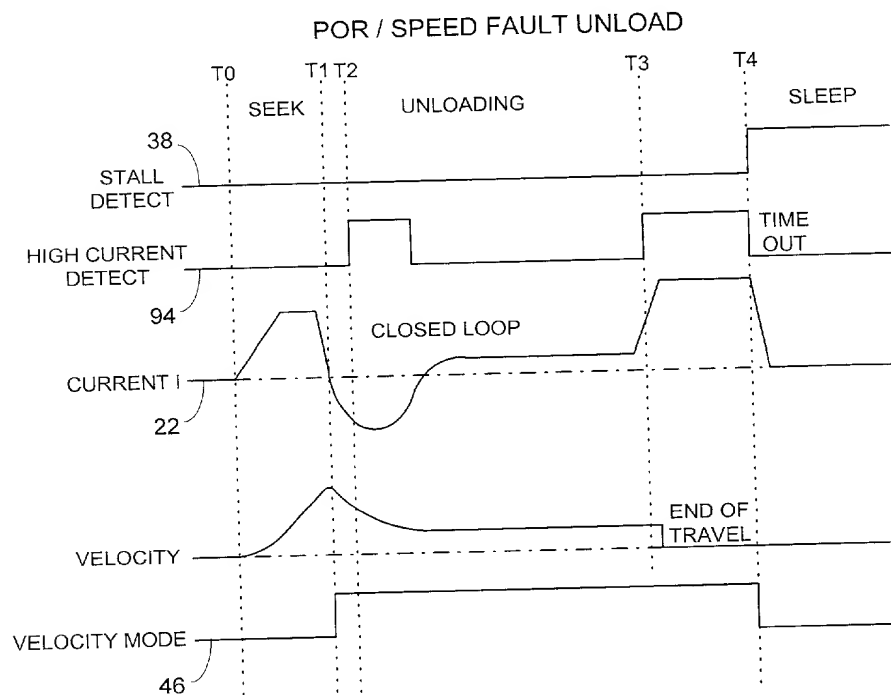


FIG. 3



**FIG. 4A**



**FIG. 4B**

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**DECLARATION FOR UTILITY OR  
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PATENT APPLICATION  
(37 CFR 1.63)**

☒ Declaration Submitted with Initial Filing **OR** ☐ Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)

**Attorney Docket Number**

K35A0680

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**COMPLETE IF KNOWN**

**Application Number**

/ Unknown

**Filing Date**

Herewith

**Group Art Unit**

Unknown

**Examiner Name**

Unknown

**As a below named inventor, I hereby declare that:**

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

**DISK DRIVE COMPRISING VCM STALL DETECTOR FOR VELOCITY CONTROL OF AN ACTUATOR ARM**

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(Title of the Invention)

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I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

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[Page 1 of 2]

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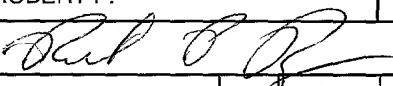
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Name of Sole or First Inventor:

☐ A petition has been filed for this unsigned inventor

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